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# Effects from Early Planting of Late-Maturing Sunflowers on Damage from Primary Insect Pests in the United States

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**Abstract:** Delayed planting is recommended to reduce damage from sunflower insect pests in the United States, including the sunflower moth, *Homoeosoma electellum* (Hulst) and banded sunflower moth, *Cochylis hospes* Walsingham. However, in some locations, planting earlier or growing later-maturing hybrids could improve yield or oil content of sunflowers which would partially offset any added costs from insect pests or their management. Because the abundance and distribution of some sunflower insects have changed since recommendations for delayed planting were developed, experimental plots were grown in 2012 and 2013 at sites in North Dakota, Nebraska, Iowa, and Illinois. Sunflowers were planted two to four weeks earlier than normal, including hybrids that flower two to three weeks later than elite commercial hybrids. The sum of seed damaged by sunflower moth, banded sunflower moth, and red sunflower seed weevil, *Smicronyx fulvus* LeConte, (i. e., total percentage) was influenced by location, but not the relative maturity of tested entries. However, when damage attributed solely to the red sunflower seed weevil was analyzed, more damaged seed were found for late-maturing entries in North Dakota and Nebraska. In addition to the trial data, current pest populations are lower than when delayed planting was first recommended and insecticide use during sunflower bloom is both common and effective. Together, these observations suggest factoring insect pests into planting time decisions may be unnecessary, except for areas with a history of problems with severe pests that cannot be managed using insecticides (e. g., sunflower midge, *Contarinia schulzi* Gagné).

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# Introduction

For annual crops, changes in planting date or relative crop maturity have been important cultural practices as part of integrated pest management. This generalization of the importance of phenology is true in cultivated sunflower, *Helianthus annuus* L., for which insect pests are generally considered to be most severe in North America, the native range of *Helianthus* spp. (Charlet *et al.*, 1997). Adjustments to planting date are commonly recommended to reduce damage from insect pests in the United States; late planting is considered a useful method to avoid yield lost by insect feeding for primary pests including the sunflower moth, *Homoeosoma electellum* (Hulst) (Mitchell *et al.*, 1978; Martinez, 1991), banded sunflower moth, *Cochylis hospes* Walsingham (Oseto *et al.*, 1989), and sunflower stem weevil, *Cylindrocopturus adspersus* (LeConte) (Rogers and Jones, 1979; Charlet *et al.*, 2007; Charlet and Aiken, 2005). However, exceptions to the value of late planting to reduce damage from insect pests also exist. In North America, increased damage from red sunflower seed weevil, *Smicronyx fulvus* LeConte, is typical in later oilseed plantings (Oseto *et al.*, 1987), while in Hungary, infestation severity for European sunflower moth, *Homoeosoma nebulellum* Den. et Schiff., is also greater in late-planted confection sunflowers (Szabó *et al.*, 2010).

Some sunflower growers in North America may continue to plant late to avoid pests and grow hybrids with maturity common to their regions, but there are some reasons to consider deviations from these traditional practices. In southern growing areas (e. g., Kansas, Texas) earlier planting could be desirable, as high temperatures during seed filling may cause reduced seed oil content (Connor and Hall, 1997), a liability under a system that adjusts grower compensation based on deviations above (premium) or below (discount) 40 % seed oil (Hulke and Kleingartner, 2014). In the northern, primary sunflower growing area, earlier planting would permit growing hybrids with later maturity, which would generally increase yield potential. Both of these strategies to improve yield or oil content of sunflowers would partially offset costs from insect pests or their management; further, for any growers who usually apply insecticides to their crop, pest avoidance through late planting might be less important. One instance where later-maturing hybrids are currently in use is for biomass sunflowers in Europe, where silage can be used to produce methane (Nassab *et al.*, 2011). However, no published research appears to exist on whether late maturity affects damage by insect pests to these biomass plantings. Floret- or seed-feeding insects may not affect some components of biomass yield (i. e., sunflower stems), but they likely reduce energy output, as the oil in sunflower heads produces a high methane content compared to other tissues (Baserga, 1998).

To assess damage from insect pests for early-planted and late-maturing sunflowers, experimental plots were grown over two years in four sites in the central United States. Observations were made on relative maturity of five sunflower entries and plant samples were used to assess damage by primary insect pests.

## Materials and methods

In 2012–2013, sunflowers were grown in Nebraska (Scottsbluff), North Dakota (Mapleton [2012] or Casselton [2013]), Iowa (Ames), and Illinois (Champaign). Iowa and Illinois are areas where sunflowers currently are not grown commercially, but sunflowers have been produced in these states in the past. Historical data and recent observations also suggest four primary insect pest species (banded sunflower moth, sunflower moth, red sunflower seed weevil and sunflower stem weevil) overwinter or migrate to all locations (in Iowa and Illinois, presumably feeding on wild Asteraceae). Within limitations of weather (excessive moisture), sunflowers were planted early relative to common practices (Table 1).

**Table 1:** Planting dates for field trials in 2012–2013.

| Location | 2012 planting date | 2013 planting date | Usual planting[a] |
|---|---|---|---|
| Nebraska | 9 May | 5 June | June 17 |
| North Dakota | 3 May | 16 May | May 29 |
| Illinois | 17 May | 24 May | n/a |
| Iowa | 16 May | 18 June | n/a |

[a]Median of usual planting dates from USDA-NASS (2010). States marked "n/a" have too few sunflower fields to generate estimates.

At each location, entries (= treatments) were arranged in a randomized complete block design with four replications. Each plot included two rows, 5.0 m in length and 0.76 m apart with 0.20 m between plants. Three late maturing entries were tested; Metharoc and F006 × M714 are both hybrids developed for biomass production in Germany, while PI 650818 is a cultivar from Argentina. Two commercial hybrids with typical maturity, Croplan 3080 and Mycogen 8H449, were tested; both lines are oilseed hybrids used as elite checks for USDA field trials in North Dakota and South Dakota, which bloom ≈ 70–75 days after planting.

No insect management (e. g., insecticide use) was made for the plants except for the insecticidal seed treatments on the commercial checks; these seed treatments should have no effects on the pest species of interest, which feed on plants when the insecticide concentrations are at orders of magnitude lower than the intended dose delivered to early-season pests (Bredeson and Lundgren, 2015). To gauge the relative maturity of the entries, weekly observations were made on the phenological stage of sunflower plants (Schneiter and Miller, 1981) in the plots in Iowa and North Dakota starting the first week of June. For the North Dakota sites, pheromone traps (wing traps baited with appropriate species lures; Scentry Biologicals, Billings, Montana, USA) were used to estimate the populations of banded sunflower moths and sunflower moths during the growing season to assess whether entries that varied in relative maturity were exposed to fewer egg-laying adults. Pheromone lures were replaced every two or three weeks to ensure consistent attraction of adult moths.

Once all plants reached physiological maturity, heads and the lower stems were removed for five plants in each plot. After drying, seed were threshed by hand from each head and placed into paper bags. Seed samples were scored by counting the total number of damaged seed and assigning damage to specific insect species based on the appearance of external and internal damage (Peng and Brewer, 1995). In 2012, 100 seed from each head were removed and scored separately as subsamples (as in Charlet *et al.*, 2008). However, data from another trial indicated combining equal volumes of seed (≈15 ml) from all heads and rating a single 200 seed sample would provide similar results with substantially less effort (correlation of $n = 30$ sample pairs, $R^2 = 0.75$; Prasifka, unpublished). As a result, 2013 samples were scored using pooled 200 seed samples. Stem sections were placed in cold (6 °C) storage until needed, then cut to include the lowest 10 cm above soil level and the number of stem weevil larvae per sample counted from digital X-ray images (MX-20: Faxitron Bioptics LLC, Tucson, Arizona, USA) of each stem (Prasifka *et al.*, 2014).

Insect damage data were analyzed using SAS statistical software (SAS Institute Inc., 2007). Data from each of the five entries were coded as either a typical- or late-maturity for analysis. Because seed damage was measured as a percentage, often with low (<10 %) values, data were square root ($x + 0.5$) transformed for analyses. Both total seed damage and damage from single insect species were evaluated. First, to determine whether there was an overall effect of sunflower maturity on damage from all seed-feeding insects, models specific to each year (2012 or 2013) were used to test whether maturity, location, and maturity × location interaction significantly determined total seed damage. Second, a similar model (independent effects of maturity, location, and maturity × location) was used to determine which factors influenced damage from each of the three seed-feeding insects. Only locations where one maturity group had at least 3 % damaged seed were used in each year and insect combination because (i) visual assignment of damaged seed to a species is an imperfect process with potential for occasional mistakes, and (ii) inclusion of locations with insignificant damage makes detection of effects present in other locations more difficult. When a maturity × location interaction was detected, the effect of location was evaluated using a *t*-test. After X-ray images of stems were examined, it was concluded the levels of infestation were too low to warrant further analysis; previous research suggests < 60 weevils per stem cause little or no damage (Rogers and Jones, 1979), which is approximately 20 weevils per X-ray (Prasifka *et al.*, 2014), several times the level seen at any of the locations.

## Results

The most notable result from the seed damage data was the extreme loss caused by sunflower moth larvae in Nebraska during 2012. Very low rainfall around the time of plant establishment (9 mm versus 63 mm average in May) and seed set (0 mm versus 33 mm average in August) stunted the plants; abiotic stress on the plants combined with insect damage resulted in 100 % seed loss for many heads. Supplemental irrigation in 2013 for the Nebraska location was used to avoid a re-occurrence of the problem. Including the extreme losses from sunflower moth in Nebraska, total seed damage from insects in 2012 was influenced by location ($F = 45.1$; df = 3, 72; $P < 0.001$), but not maturity or a maturity × location interaction. A similar result was seen in 2013, with location as the only significant factor in the percentage of insect-damaged seed ($F = 38.9$; df = 3, 72; $P < 0.001$) (Table 2).

For individual insect pests, significant (>3 %) damage from red sunflower seed weevil was observed in Nebraska and North Dakota in both years. In 2012, weevil damage was influenced by both location ($F = 20.66$; df = 1, 36; $P < 0.001$) and maturity ($F = 6.21$; df = 1, 36; $P \leq 0.017$) with greater damage to late-blooming entries. For 2013, location ($F = 37.24$; df = 1, 36; $P < 0.001$) and a maturity × location interaction ($F = 4.03$; df = 1, 36; $P = 0.026$) significantly affected damage by the red sunflower seed weevil. Though the main effect test for maturity was not significant

**Table 2:** Insect damage by relative maturity in 2012–2013 trials with early sunflower planting.

| *Year* Location | Maturity | Insect-damaged seed (%)[a] | | | | Sunflower stem weevils (#)[b] |
|---|---|---|---|---|---|---|
| | | Total | Red sunflower seed weevil | Sunflower moth | Banded sunflower moth | |
| *2012* | | | | | | |
| Nebraska | Typical | 73.7 | **0.5** | **73.2** | 0.0 | 3.7 |
| | Late | 59.2 | **3.2*** | **55.7** | 0.3 | 3.0 |
| North Dakota | Typical | 12.5 | **4.0** | **4.3** | **4.2** | 0.0 |
| | Late | 13.4 | **6.9*** | **3.7** | **2.9** | 0.1 |
| Illinois | Typical | 13.0 | 0.4 | **9.8** | **4.5** | 0.2 |
| | Late | 13.9 | 0.4 | **11.4** | **2.0** | 0.6 |
| Iowa | Typical | 8.3 | 0.1 | **7.7** | 0.5 | 0.0 |
| | Late | 5.8 | 0.1 | **5.3** | 0.5 | 0.0 |
| *2013* | | | | | | |
| Nebraska | Typical | 14.0 | **10.1** | 1.3 | **2.6** | 1.4 |
| | Late | 14.3 | **10.1** | 1.1 | **3.0** | 1.1 |
| North Dakota | Typical | 5.6 | **0.5** | 1.1 | **4.1** | 0.0 |
| | Late | 12.2 | **4.1*** | 1.6 | **6.5** | 0.1 |
| Illinois | Typical | 4.7 | 0.4 | 1.5 | 2.8 | 2.3 |
| | Late | 3.7 | 1.2 | 1.1 | 1.4 | 2.3 |
| Iowa | Typical | 0.3 | 0.0 | 0.2 | 0.1 | 0.0 |
| | Late | 1.1 | 0.0 | 0.5 | 0.6 | 0.0 |

[a]Effects of maturity tested for the insect and location combinations in bold text. Asterisks (*) indicate significant ($P < 0.05$) differences ($F$- or $t$-test) between two normal maturity hybrids and three late-maturing entries.
[b]Weevil larvae per X-ray image of lowest 10 cm of stem. Not tested statistically because of very low weevil abundance relative to economic injury level.

($F = 4.03$; df = 1, 36; $P = 0.052$), the interaction prompted separate $t$-tests for the effect of maturity, which showed significantly greater damage in late-maturing entries in North Dakota ($t = -3.66$, df = 18, $P = 0.002$) (Table 2).

Banded sunflower moth damage in 2012 exceeded 3 % in North Dakota and Illinois, but no model effects (maturity, location, and maturity × location interaction) were found. In 2013, banded moth damage in Nebraska and North Dakota were included in testing, but only an effect of location was found ($F = 7.44$; df = 1, 36; $P < 0.001$), with greater damage in North Dakota (Table 2). Traps baited with banded sunflower moth pheromone in North Dakota show trends that suggest populations were relatively high for the late pre-bloom period of all entries in both years (Figure 1). Field observations in Iowa suggest similar relative maturities,

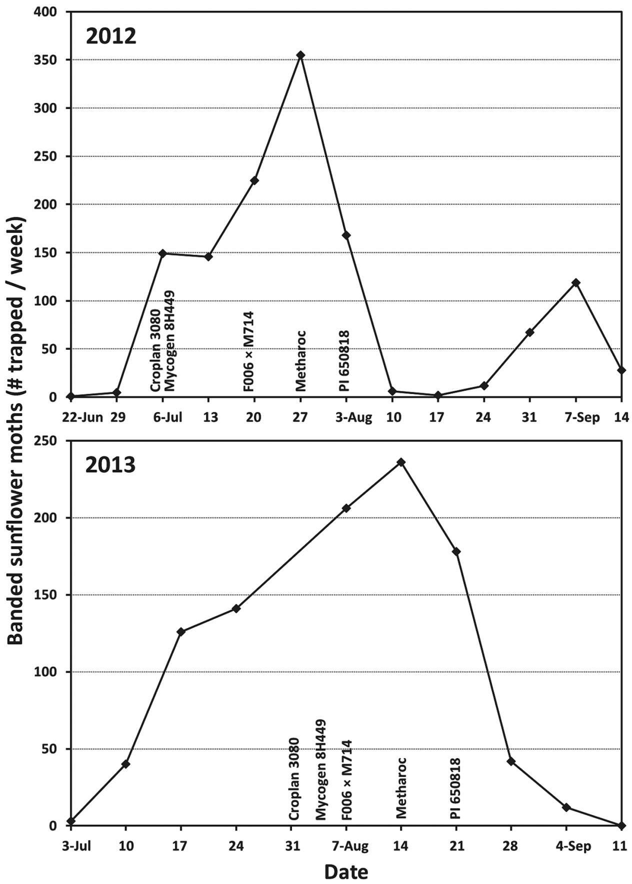


**Figure 1:** Relative abundance of banded sunflower moth adults and occurrence of suitable oviposition stage (late bud [R4]; Schneiter and Miller, 1981) for sunflower entries in North Dakota, 2012–2013.

with flowering phenology delays relative to the elite hybrids of one (F006 × M714), two (Metharoc), or three (PI 650818) weeks.

While sunflower moth caused the most damage among the seed-feeding insects and is generally considered sensitive to plant maturity, damage from sunflower moth larvae was only affected by location ($F = 51.54$; df = 3, 72; $P < 0.001$) in 2012, and was consistently low (< 2 %) in 2013. Sunflower moth pheromone traps in North Dakota show relatively low populations of adult moths covering the bloom period for all entries in 2012 (Figure 2), while just a single adult sunflower moth was captured in 2013.

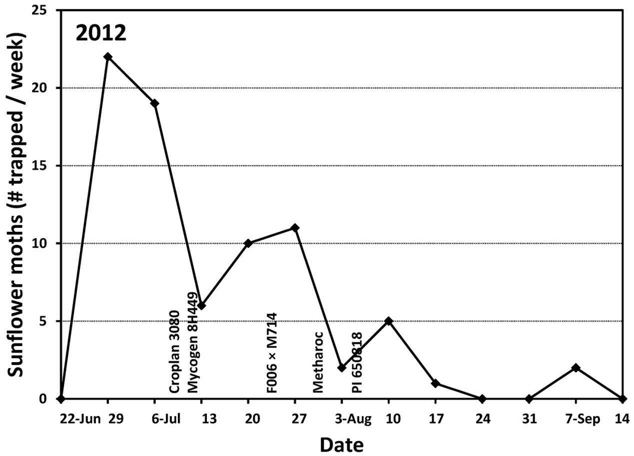


**Figure 2:** Relative abundance of sunflower moth adults and start of suitable oviposition stage (bloom [R5]; Schneiter and Miller, 1981) for sunflower entries in North Dakota, 2012.

# Discussion

The cultural practice of adjusting planting dates in sunflowers to avoid insect damage is supported not only by research in sunflowers, but by the benefits of modified planting dates (or selection of early- or late-maturing varieties) as a component of integrated pest management (IPM) in many other annual crops. The underlying principle of altering plant maturity for pest management is avoidance by modifying phenology, specifically reducing synchrony between the susceptible stage of the crop and the damaging stage of the insect. For example, delayed planting of winter wheat until after so-called fly-free dates has been an important tactic to avoid damage by Hessian fly, *Mayetiola destructor* Say, in the United States (Buntin *et al.*, 1992). Recent research in Spain suggests that early maturity in maize helps to limit damage from larvae of Mediterranean and European corn borers (*Sesamia nonagrioides* Lefebvre and *Ostrinia nubilalis* Hübner, respectively), as kernels and other tissues are tougher on the more mature plants (Ordas *et al.*, 2013). Early-maturity in soybean inbred lines also appears partially responsible for reduced seed damage by the pod borer, *Leguminivora glycinivorella* (Mats.) Obraztsov in Asia (Zhao *et al.*, 2008).

Previous data on how planting date affects losses from sunflower moth (Mitchell *et al.*, 1978) and banded sunflower moth (Oseto *et al.*, 1989) suggests late-maturing entries should exhibit decreased seed damage. However, for early-planted sunflowers in 2012–2013, differences in maturity of two to three weeks generally had little effect on the damage from seed- or stem-feeding insects. Data on adult populations of moth pests were only available for North Dakota, but trap captures suggest both normal and late-maturing entries were exposed to similarly high populations of banded sunflower moth. It is possible that while damage from seed-feeding caterpillars is reduced in some instances, the long duration of adult emergence for a single generation (for banded sunflower moth; Figure 1) or the occurrence of multiple generations (for sunflower moth; Kikukawa and Chippendale, 1984) may make benefits from late development inconsistent. Similar to the results in 2012–2013, Charlet and Busacca (1986) saw no effect of a three-week delay in planting time for damage by banded sunflower moth. On the other hand, damage from seed weevils in 2012–2013 was increased in late-maturing sunflowers in three of four location and year combinations tested. This difference seems attributable to pest biology, as the single generation of red sunflower seed weevil adults emerges late relative to the other seed-feeding pests.

Early planting also has been associated with increased numbers of sunflower stem weevils (Charlet and Aiken, 2005), but the numbers of weevils found in 2012–2013 samples were low relative to levels considered to be economically damaging. Also, Charlet *et al.* (2007) note that in locations where stem weevil adults are abundant, early-season insecticide applications (V8 or V12) are effective; because an insecticide application to very small plants can be made from the ground rather than by aerial application, the costs of sunflower stem weevil management can be very low, limiting the risks of early-planting.

Overall, insect damage data on early planted, late-maturing sunflowers suggest it is reasonable to reevaluate cultural practices in sunflower related to planting times or relative maturity of hybrids in North America – particularly when using earlier planting or longer-season hybrids could improve yield or convenience for growers. Aside from the data presented from 2012–2013 indicating little benefit from 2–3 week differences in maturity, other reasons to reconsider practices developed decades ago include: (i) the observation that some pest populations are very low relative to 1970s and 1980s (Charlet, 2002), and (ii) that insecticide use during sunflower bloom is so common and effective (see survey data from National Sunflower Association, www.sunflowernsa.com/growers/yield-and-survey/sunflower-crop-survey/). Combined, these data suggest factoring insect pests into planting time decisions may have negative or marginal value, except in cases where there have been issues with severe pests without other management options (e. g., sunflower midge, *Contarinia schulzi* Gagné [Anderson and Brewer, 1991]).

## Conclusions

Total damage by seed-feeding pests of sunflower was not influenced by differences in maturity for early-plantings of sunflower over two years in four states. While damage from red seed weevils was greater for entries with late maturity, low overall pest populations and the efficacy of insecticide applications suggest decisions regarding planting time and hybrid maturity often should be made for agronomic reasons other than avoidance of insect pests.

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